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The IR Properties of Interacting and Merging Galaxies to z = 1.3

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Abstract. We attempt to understand the role of collisions and mergers on the IR-bright galaxy population since a redshift of ∼1.5, where the median star formation rate is falling the most rapidly. Using over a thousand 24μm sources from the Extragalactic First Look Survey contained with 50 HST/ACS fields, we classify their morphologies using both the CAS automated method, and a subjective "human inspection" method. We conclude that out to z = 1.5, both the 24μm luminosity and the 24/6.8μm color is not strongly coupled to CAS morphology or merger state. Dusty AGN, on the other hand, seem both more luminous and more symmetrical than star formation-dominated systems.

1. Introduction

Deep surveys of the universe with ISO (Elbaz et al. 1999; Fadda et al. 2002), concluded that LIRGs and ULIRGs become increasingly dominant at higher redshifts, and may be responsible for between 35-85% of the star formation density of the universe out to z = 1. Although there is evidence from Spitzer number counts (Papovich et al. 2004) that the most IR luminous epoch may be at an even higher redshift, the ISO studies showed that more than 1/3 of the galaxies detected in deep surveys were merging or interacting (Flores et al. 1999). In this current paper, we will use data from the Spitzer First Look Survey (Fadda et al. 2004) to ask two very simple questions: 1) Are galaxies with disturbed/collisional morphologies more IR luminous, or exhibit different infrared colors than those optically disturbed galaxies and 2) are dusty AGNs (based on an IRAC color criteria) different in the IR properties or collisional morphologies from star–formation dominated systems? Spitzer provides the first opportunity for astronomers to probe the IR-properties of statistically significant samples of galaxies over a wide redshift range.

2. Sample Selection

IR sources at 24μm were selected from the Spitzer FLS (4-square degrees in area) above a 3-sigma threshold of 80μJy. Optical counterparts were found for 1176 sources which fell within the 50 overlapping HST ACS fields near the center of the FLS, covering an area of 0.14 square degrees in the F814W filter. Good morphologies were obtained for sources with I < 23.5. Of these sources, 383 sources had redshifts based on a cross-correlation with our WIYN/Hydra (Marleau et al. 2005) and Keck II/Deimos (Choi et al. 2005) redshift catalogs, and addition redshifts from the SDSS. Galaxies were additional separated into dusty AGN–dominated and star formation–dominated galaxies using the IRAC color criteria of (Lacy et al. 2004).

Study of the Morphologies

Galaxy morphologies from the ACS images were assessed using two methods. The first is the CAS method of (Conselice 2003), which uses the Concentration (C), Asymmetry (A) and Clumpiness (S) measures based on the HST light distributions within each object. The method, which does not involve significant human intervention, was applied to composite systems and separated systems within a target radius of 3 arcsecs from the centroid of the 24μm source. Human intervention was needed to decide whether to count the system as "composite" (i.e. a single merged system) or as two separate objects. This will be discussed in a separate paper (Appleton et al. in preparation). A second method of morphological classification was applied by human inspection of each potential optical counterpart to the IR source in the HST images. Galaxies were classified as I(solated), P(aired-non-interacting), T(idal pair), C(ontact pair) and M(erger-Violent). This scheme suffers from being highly subjective, being based on a comparison between the appearance of the target galaxy with that of nearby galaxy merger sequences, as well as numerical models (Schweizer 1996; Hernquist 1992; Mihos 1995).

Fig. 1a and b show that there is no obvious trend in rest-frame 24μm luminosity (k-corrected using M82 as a template) and interaction morphology (a) or CAS indices (b) over the sample. Although a rich variety of different morphologies were present over the full redshift range, these did not correlate with luminosity or F(24/5.8)μm color (see Fig. 2). Only one class of object showed a clear CAS signature–galaxies with inverted F(24/5.8) colors. These object were found to have the morphological properties of elliptical systems, and all had low-redshifts ($z < 0.2$–The inverted colors being consistent with SEDs dominated by near-IR stellar continuum light from relatively quiescent galaxies). A strong correlation was found between the merger stage, as defined by the subjective method, and the standard CAS parameters: merging systems showing large asymmetries consistent with the work of (Conselice 2003). This provides a strong confirmation that we are able to correctly identify optically–obvious merging systems with CAS–a reality check that is important in this work.

Conclusions

Our work with the Spitzer FLS sample leads to the following conclusions:

1) The rest-frame 24μm luminosity of a galaxy out to $z > 1.3$ is NOT strongly coupled to optical structure or merger stage, 2) The F(24/6.8)μm color index is NOT strongly coupled to CAS morphology, with the exception of inverted or flat spectra which appear to be low-z elliptical galaxies, 3) Dusty AGN, as defined by their IRAC colors, seem more luminous (Fig. 3), more compact and symmetrical (as defined by the C and A parameters) than similar SB-dominated galaxies. The fraction of AGN/SB seems roughly fixed with redshift out to $z = 1.3$.

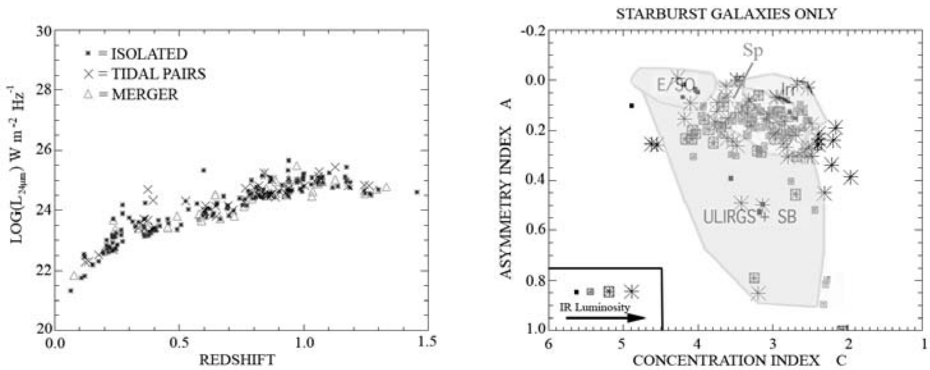

Figure 1. (a), The 24μm k-corrected monochromatic luminosity as a function of interaction class; (b), The Asymmetry (A) and Concentration (C) for the star formation (non-AGN) sample as a function of 24μm luminosity (increasing symbol size). Also marked are the regions occupied by various classes of galaxy (Conselice 2003).

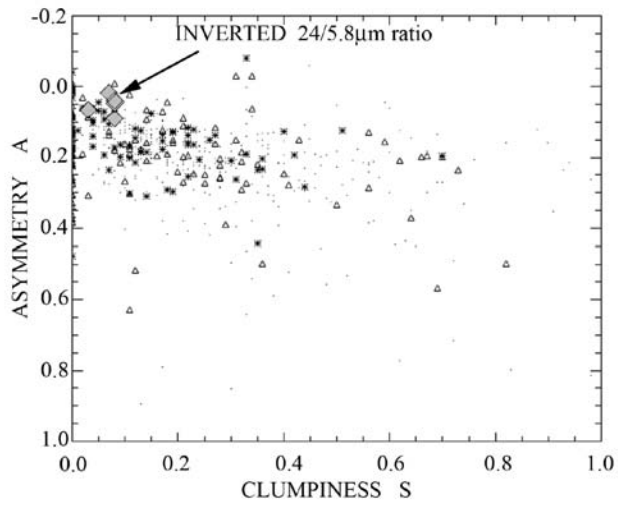

Figure 2. The Clumpyness (S) versus Asymmetry (A) for galaxies with a range of $24/5.8\mu$m flux ratios in the sample (ranging from $-1 < \mathrm{Log}(24/5.8)\mu$m < 2). The only population which shows segregation in this CAS plot are those with a inverted (i.e. negative) ratio. These galaxies are all low-z elliptical galaxies which are dominated at IRAC wavelengths by a strong stellar continuum.

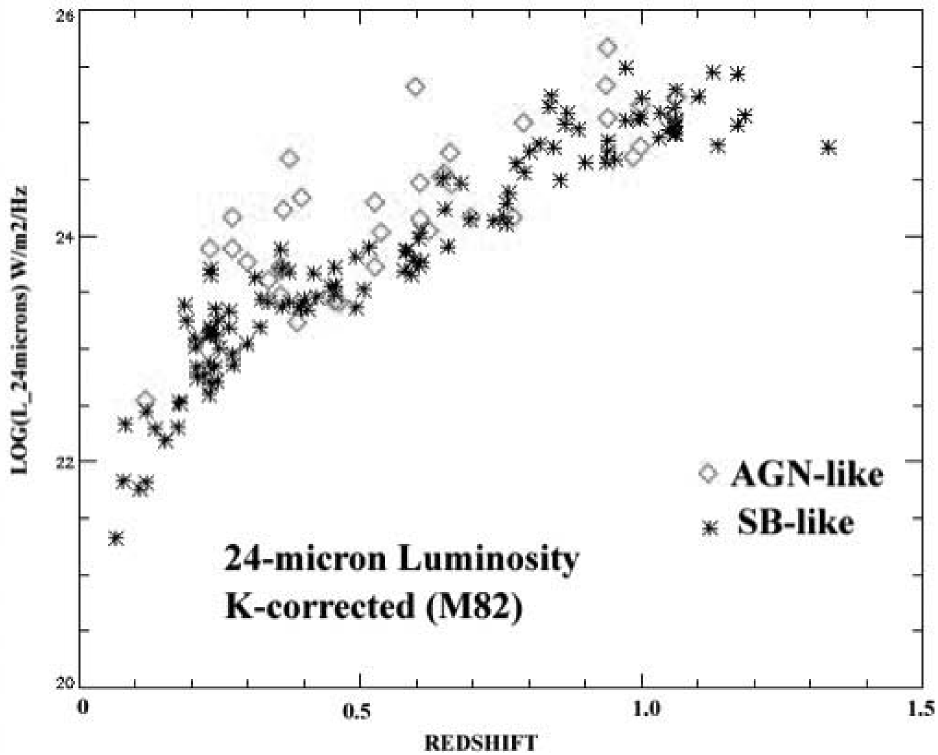

Figure 3. The 24μm monochromatic luminosity of AGN-like and Starburst-like galaxies as a function of redshift. These dusty AGN's are defined as fulfilling the IRAC color criteria of (Lacy et al. 2004). Note that at a give redshift, the dusty AGN are more luminous at 24μm than their SB counterparts.

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